

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
30 May 2002 (30.05.2002)

PCT

(10) International Publication Number  
**WO 02/42716 A2**

(51) International Patent Classification<sup>7</sup>:

**G01C**

(21) International Application Number:

PCT/US01/44329

(22) International Filing Date:

27 November 2001 (27.11.2001)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

60/253,206 27 November 2000 (27.11.2000) US

(71) Applicant (*for all designated States except US*): **MICROSENSORS INC.** [US/US]; 3001 Redhill Avenue, Suite 4-109, Costa Mesa, CA 92612 (US).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **EIDE, Floyd, K.** [/US]; 3889 Mistral Drive, Huntington Beach, CA 92649 (US). **NGUYEN, Andy, A.** [/US]; 9882 West Ramm Drive, Anaheim, CA 92806 (US).

(74) Agent: **LIN, Vic, Y.**; Myers, Dawes & Andras LLP, Suite 1150, 19900 MacArthur Boulevard, Irvine, CA 92612 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.



**WO 02/42716 A2**

(54) Title: WAFER EUTECTIC BONDING OF MEMS GYROS

(57) Abstract: A plurality of gyro packages are manufactured on a wafer scale. At least one cap wafer having a plurality of getters disposed in corresponding recesses is coupled to a gyro wafer having a plurality of gyros. The resulting wafer assembly comprises a cap portion coupled to a base portion. Accordingly, a getter and an associated gyro is enclosed in each gyro package. Through eutectic bonding, each getter and corresponding gyro is vacuum sealed in the gyro package. Through eutectic bonding, each getter and corresponding gyro is vacuum sealed in the gyro package. The wafer assembly may then be diced along predefined elongate through-holes in the cap wafer to provide separate gyro packages. Methods for manufacturing and retrofitting gyro packages and assemblies are provided.

## WAFER EUTECTIC BONDING OF MEMS GYROS

### *Related Applications*

5 This application relates to and claims priority from U.S. Provisional Application Serial No. 60/253,206 entitled WAFER EUTECTIC BONDING OF MEMS GYROS, filed on November 27, 2000, the disclosure of which is incorporated herein by reference.

## BACKGROUND OF THE INVENTION

10

### *1. Field of the Invention*

This invention relates to wafer-level packaging of gyros.

### *2. Description of Prior Art and Related Information*

15 Micro-electro mechanical systems (MEMS) gyros are used in a variety of applications. In gyro package, it is desirable to provide a vacuum in order to facilitate the damping characteristics of the seismic mass of the gyro's resonant microstructure. In conventional approaches, the vacuum seal may be insufficient, leading to suboptimal performance and a shorter lifespan of the gyro. Furthermore, many bonding  
20 procedures result in negative effects on the sensor. For example, glass frit bonding may lead to organic contamination of the gyro sense elements.

A major challenge in wafer packaging is to maintain a vacuum for an extended service life, which is on the order of 15 years in the automotive industry, for example. Vacuum decay occurs over time due to various factors including poor processing and  
25 outgassing. Gyro packages are also typically expensive to produce. It would be advantageous to manufacture gyro packages with a longer lifespan at a lower cost.

## SUMMARY OF THE INVENTION

The present invention provides structures and methods which overcome the deficiencies of the prior art.

In one aspect, a gyro package is provided. The gyro package comprises a base including a MEMS gyro, a metallic seal ring disposed on the base, a cap defining a recess, a getter coupled to the cap and disposed in the recess, a first alloy disposed on a bottom surface of the cap, and a second alloy coupled to the metallic seal ring and the first alloy so as to seal in the gyro and the getter. The second alloy and the metallic seal ring comprise a common metal, such as germanium. The second alloy and the first alloy comprise a common metal, such as gold. The second alloy preferably comprises a preform.

In a further aspect, a gyro package comprises a base including a MEMS gyro, a metallic seal ring disposed on the base, a cap defining a recess, a getter coupled to the cap and disposed in the recess, a first alloy disposed on a bottom surface of the cap, a spacer lattice disposed between the cap and the base, the spacer lattice having a top lattice surface and a bottom lattice surface, and a second alloy disposed on the top lattice surface and the bottom lattice surface. The second alloy is coupled to the metallic seal ring and the first alloy so as to couple the spacer lattice to the cap and the base.

The package further comprises a first preform coupling the first metallic alloy to the second alloy on the top lattice surface, and a second preform coupling the metallic seal ring to the second alloy on the bottom lattice surface.

A retrofitted gyro package is also provided. The package comprises a base including a MEMS gyro, a first cap coupled to the base so as to form a first cavity, a second cap coupled to the first cap so as to form a second cavity, the first cap defining an aperture in fluid communication with the first cavity and the second cavity, and a getter coupled to the second cap and disposed in the second cavity. A vacuum is defined between the second cap and the base.

The gyro package further comprises a first alloy applied to a bottom surface of the second cap. The getter is soldered to the first alloy. A metallic seal ring is applied to a top surface of the first cap and coupled to the first alloy. The metallic seal ring is coupled to the first alloy with a preform.

A method for manufacturing gyro packages on a wafer scale is provided. The method comprises the steps of providing a gyro wafer with a plurality of base portions having gyros, providing a cap wafer with a plurality of cap portions coupled to a plurality of getters, activating the getters, and eutectically coupling the cap wafer to the gyro wafer to form a plurality of vacuum sealed gyro packages. A first alloy is applied to a bottom surface of the cap wafer. The getters are soldered to the first alloy. A second alloy is applied to a top surface of the gyro wafer.

The step of applying a second alloy to a top surface of the gyro wafer comprises the step of disposing seal rings composed of the second alloy onto the top surface of the gyro wafer. The step of eutectically bonding the cap wafer to the gyro wafer to form a plurality of vacuum sealed gyro packages comprises the step of bonding a third alloy to the first alloy and the second alloy. The step of bonding a third alloy to the first alloy and the second alloy comprises bonding a preform composed of the third alloy to the first alloy and the second alloy. The step of eutectically coupling the cap wafer to the gyro wafer to form a plurality of vacuum sealed gyro packages comprises the step of coupling the cap wafer and the gyro wafer to an intermediate wafer. The step of coupling the cap wafer and the gyro wafer to an intermediate wafer comprises the step of coupling the cap wafer and the gyro wafer to a spacer lattice.

In a further aspect, a method for manufacturing a gyro package comprises applying a first alloy to a bottom side of a cap, coupling a getter to the first alloy on the bottom surface of the cap, activating the getter, providing a base with a MEMS gyro on a top side, applying a seal ring on the top side of the base, and coupling the cap to the base with a second alloy so as to enclose the getter and the MEMS gyro. The step of applying a seal ring on the top side of the base comprises the step of applying a third alloy on the top side of the base.

The method further comprises the steps of providing the first alloy and the second alloy with at least one common metal as well as providing the seal ring and the second alloy with at least one common metal. The step of coupling the cap to the base with a second alloy so as to enclose the getter and the MEMS gyro comprises the step of eutectically bonding the first alloy and the seal ring to the second alloy.

A method is also provided for retrofitting an existing gyro package having a base portion with a gyro, and a existing cap portion coupled to the base portion. The method comprising the steps of forming a hole in the existing cap portion, coupling a getter to a

bottom side of an additional cap portion, activating the getter, and coupling the additional cap portion to a top side of the existing cap portion to form a vacuum sealed cavity in which the getter and the gyro are disposed.

A first alloy is applied to a bottom side of the additional cap portion. The method  
5 further comprises the steps of applying a second alloy to a top side of the existing cap portion and coupling the first alloy to the second alloy with a third alloy. The step of applying a second alloy to a top side of the existing cap portion comprises the step of applying a seal ring to the top side of the existing cap portion. The step of coupling the first alloy to the second alloy with a third alloy comprises the step of coupling the first  
10 alloy to the seal ring with a preform.

The invention, now having been briefly summarized, may be better appreciated by the following description of preferred embodiments and reference to the associated drawings.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1a is a top view of the bonded wafer showing cap wafer bonded to MEMS gyro wafer while exposing bond pads;

5 Figure 1b is an exploded, cross-sectional side view of a preferred embodiment employing a eutectic seal with an aluminum alloy;

Figure 2 is an exploded, cross-sectional side view of a preferred embodiment employing a eutectic seal with a gold alloy;

Figure 3 is an exploded, cross-sectional side view of an alternate embodiment having a spacer lattice;

10 Figure 4 is an exploded, cross-sectional view of a further embodiment;

Figure 5 is a binary phase diagram for an eutectic alloy of aluminum and germanium.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS AND BEST MODE OF THE INVENTION

The invention and its various embodiments can now be better understood with the following detailed description wherein illustrated embodiments are described. It is  
5 to be expressly understood that the illustrated embodiments are set forth as examples and not by way of limitations on the invention which is ultimately defined in the claims.

A first preferred embodiment of a gyro wafer assembly 10 is shown in Figure 1a. The wafer assembly 10 comprises a plurality of gyro packages which may be separated. As described further below, a method is provided for manufacturing a  
10 plurality of gyro packages on a wafer scale. Thus, as shown in Figure 1b, a cap wafer 22 comprising a plurality of cap portions, or caps, 24 is coupled to a base, gyro wafer 26 comprising a plurality of base portions, or bases, 28 to form a plurality of separable gyro packages 20.

Figure 1b illustrates two, separated gyro packages 20, shown in an exploded,  
15 cross-sectional view. In the first preferred embodiment shown in Figures 1a and 1b, eutectic bonding is employed. The cap wafer 22 is coupled to the gyro wafer 26 such that a single cap portion 24 is coupled to a corresponding base portion 28. Each base portion 28 preferably includes a micro-electro mechanical systems (MEMS) gyro, or sensor, 31. The gyros 31 are provided on a top side 33 of the gyro wafer 26. A seal ring 35 coupled to the top side 33 of the base portion 28 preferably comprises a first eutectic alloy. In the first preferred embodiment, the first eutectic alloy is composed of aluminum and germanium. A binary phase diagram of an aluminum germanium alloy system is shown in Figure 5. In Figure 1b, the aluminum-germanium seal ring 35 is preferably coupled to an aluminum bond pad 37 disposed on the top side 33 of the  
20 base portion 28.  
25

Aluminum alloys may be desirable since certain wafer printing machinery already employ aluminum alloys. After the polycrystalline silicon of the gyro wafer 26 and aluminum bond pads 37 are structured by mask, a thin layer of aluminum in the range of two microns, for example, is deposited by sputtering the cap wafer seal ring. This is  
30 followed by another layer of germanium in the range of 1-1.5 microns, for example. It is to be expressly understood that these ranges are set forth as examples and not as limitations. The gyro wafer 26 is then mounted to an alignment fixture.

In Figures 1a and 1b, a bottom side 39 of the cap wafer 22 includes a plurality of recesses 42 in which getters 44 are to be placed according to the invention. The cap wafer 22 further includes elongate through-holes 46, shown in Figure 1a, that serve as dicing lines to form individual packages 20 after the cap wafer 22 is eutectically bonded 5 to the gyro wafer 26 and/or another cap wafer as described further below.

A second alloy 48 is applied to the bottom side of the cap wafer 22. In particular, the silicon cap wafer 22 is sputtered with titanium-tungsten (TiW) followed by 100 microns of gold (Au). A solderable getter paste 44 obtained, for example, from SAES Getters can be screen printed to the silicon cap wafer 22 and then solder joined with 10 gold-germanium (Au-Ge) solder preform 51. The solderable getter paste 44 is a mixture of Ti-St 707. SAES Getters' St 707 is a ternary Zr-V-Fe alloy. After the getter paste 44 is screen printed, getter activation is performed at 340°C for roughly 2 hours. The temperature is ramped up to 365°C for roughly half an hour to solder join each 15 getter 44 to the silicon cap wafer 22. The process to activate each getter 44 is performed under a  $10^{-5}$  or better vacuum level and at a distance from 2-6 inches from the silicon gyro wafer 26.

Using an alignment fixture, the silicon cap wafer 22 with the mounted getters 44 is aligned with and bonded to the gyro wafer 26 with gold-germanium (Au-Ge) preform 53. A eutectic seal is formed by maintaining the temperature at 365°C for roughly half 20 an hour. It will be appreciated that the preform 53 comprises a common metal with the seal ring 35, namely, germanium, and a common metal with the cap alloy 48, namely, gold.

In Figure 2, a second preferred embodiment of a gyro wafer assembly 100 comprises eutectic bonding with a gold alloy. Figure 2 illustrates a gyro wafer assembly 25 100 in part. In particular, Figure 2 illustrates in exploded view a single gyro package 110 which results after dicing of the wafer assembly 100. A seal ring 112 coupled to a base portion 114 of a gyro wafer 116 is composed of a eutectic gold-tin (Au-Sn) alloy. Unlike the Al/Ge eutectic bonding approach shown in Figures 1a and 1b, gold deposition is used in the processing of the MEMS gyro wafer 116 in Figure 2 as well as 30 the gyro wafer in a third preferred embodiment shown in Figure 3. Gold alloys are preferable because they provide stronger adhesion and a better hermetic seal, thereby providing a longer lasting vacuum. The bond pads 118 and metal seal rings 112 are sputtered with gold. A gold alloy 121 is applied to a bottom side 123 of a cap wafer

125. In particular, the cap wafer 125 is sputtered with titanium-tungsten (Ti-W) followed by 100 microns of gold.

Each base portion 114 preferably includes a MEMS gyro 127 on a top side 129.

Getters 132 are coupled to the bottom side 123 of the cap wafer 125, preferably with a 5 getter 132 disposed in each recess 134 of each cap portion 136. The joining and activation of the getters 132 follow the same procedure discussed above in relation to Figures 1a and 1b.

The cap wafer 125 is then aligned with and joined to the MEMS gyro wafer 116 using a gold-tin eutectic preform 141. The Au/Sn vacuum seal is performed at 320°C 10 for half an hour.

Another bonding approach is to eutectically bond directly over a metallized cap wafer. The processing conditions for this bonding method is similar to the process discussed above in connection with Figure 2.

Figure 3 illustrates a third preferred embodiment of a wafer assembly 200 in part.

15 In particular, Figure 3 illustrates in exploded view a gyro package 210 which results after dicing of the wafer assembly 200. As shown, a silicon lattice wafer 212 may be used as an intermediate spacer to vacuum seal a MEMS gyro wafer 214. The intermediate spacer lattice 212 provides extra space allowing more getter paste to be added to a silicon cap wafer 216. A first alloy 218 composed of titanium-tungsten and 20 gold (TiW-Au) is applied to a bottom side 221 of the cap wafer 216. Getters 223 are soldered to the first alloy 218 using a gold-germanium eutectic solder 225. A getter 223 is preferably disposed in a recess 227 of each cap portion 229.

A second alloy 232 preferably composed of titanium-tungsten-gold (TiW-Au) is applied to a top side 234 and a bottom side 236 of the lattice wafer 212. The cap wafer 25 216 is then aligned with and joined to the silicon lattice wafer 212 using a gold-tin (Au-Sn) eutectic solder, or preform, 238. The gold-tin (Au-Sn) vacuum seal is performed at 320°C for half an hour. The cap wafer 216 and joined silicon spacer 212 are then aligned with and coupled to the MEMS gyro wafer 214, also using gold-tin (Au-Sn) eutectic solder 238 that is coupled to seal rings 241 on a top side 243 of the cap wafer 30 216. The gold-tin (Au/Sn) vacuum seal is also performed at 320°C for half an hour.

The resulting wafer assembly 200 thus comprises a plurality of separable gyro packages 210, wherein each package 210 includes a cap portion 229 coupled to a lattice portion 245 which is coupled to a base portion 247. The lattice portion 245

provides an expanded enclosure 249 of the getter 223 and corresponding gyro 252. The expanded enclosure, or cavity, 249 is vacuum sealed by eutectic bonding of gold alloys. It will be appreciated that the enclosure 249 defines an enlarged

It will be appreciated that the use of a gold alloy to accomplish the eutectic  
5 bonding between the wafers 212, 214, 216 requires a lower sealing temperature, namely at 320°C, than an aluminum alloy, for instance. Thus, gold alloys are preferable so as to avoid metal oxidation and to provide better adhesion strength.

Figure 4 illustrates a fourth preferred embodiment of a wafer assembly 300 in part. More specifically, Figure 4 illustrates in exploded view a single gyro package 310  
10 which results after dicing of the wafer assembly 300. In particular, a method is provided for retrofitting an existing gyro package to include a getter. For example, the process and associated structure in accordance with the fourth preferred embodiment may be preferable if a package sub-assembly 312 of a cap portion 318 coupled to a base portion 321 with a gyro 323 already exists. The method also comprises wafer-scale  
15 retrofitting wherein an existing wafer sub-assembly 312 of a silicon cap wafer 314 coupled to a MEMS gyro wafer 316 may be retrofitted to include an additional cap wafer with a plurality of getters.

In Figure 4, a package sub-assembly 312 is retrofitted to include a getter 325 by coupling a getter 325 to a second, or additional, cap portion 327 and coupling the  
20 second cap portion 327 to the first, or existing, cap portion 318 with an eutectic bond. A first, or existing cavity, 329 is defined by the first cap portion 318 and a base, gyro portion 321. An aperture 332 is formed in the existing cap portion 318 in order to provide fluid communication between the first cavity 329 and a second cavity 334 defined by the second cap portion 327 and the first cap portion 318. As an example  
25 and not by way of limitation, the aperture 332 may have diameter of 120 microns. The MEMS gyro wafer may be structured according to Bosch's glass sealing procedure. All bond pads 336 may be sputtered with aluminum in accordance with Bosch's CMOS processing.

As an example and not by way of limitation, the existing package sub-assembly  
30 312 may include a cap portion 318 bonded to a MEMS gyro base portion 321 in vacuum, using a frit glass seal ring 338. This procedure is performed and processed by Bosch Corporation, for example.

A first alloy 341 preferably composed of titanium-tungsten-gold (TiW-Au) is applied to a top side 343 of the first cap portion 318. In the preferred embodiment, the first alloy 341 is provided in the form of a seal ring 341. In particular, titanium-tungsten is sputtered onto the top side 343 of the first cap portion 318, followed by preferably 5 100 microns of gold.

The joining and activation of the getter 325 to the top silicon cap portion 327 also follows the same procedure discussed above using Au/Ge eutectic solder 349. In particular, a second alloy 345 preferably composed of titanium-tungsten-gold is applied to a bottom side 347 of the second cap portion 327. The getter 325 is coupled to the 10 second alloy 345 with a gold-germanium eutectic solder 349. The top cap portion 327 is aligned with and joined to the first cap portion 318. The vacuum seal of the two cap wafers 318, 327 is formed using a gold-tin (Au-Sn) solder, or preform, 352 at 320°C for half an hour.

Once retrofitted, it will be noted that the existing cap portion 318 becomes an 15 intermediate cap portion whereas the additional cap portion 327 becomes the uppermost cap portion. It will be appreciated that the surface area of metalized surfaces rather than the volume is the source of outgassed species. As a result, an existing sub-assembly is retrofitted with a gettering system that enables a 15-year lifetime of the retrofitted gyro package 310.

20 A method for wafer-scale retrofitting is also provided. In retrofitting a wafer sub-assembly, a plurality of holes is formed in the existing cap wafer to correspond to each gyro on the gyro wafer. A seal ring composed of a first alloy is applied to the top side of the existing cap wafer. A second, additional cap wafer has a bottom side to which a second alloy is coupled. A plurality of getters are provided to correspond to each gyro 25 on the gyro wafer. The getters are disposed in the recesses of the second cap and soldered to the second alloy with a eutectic solder. After the getters are joined and activated, the second cap is coupled to the existing cap with solder preform composed of a third alloy. The retrofitted wafer assembly will include a plurality of separable wafer packages wherein a getter is provided for each gyro.

30 In each of the preferred embodiments, it will be appreciated that a plurality of gyro packages are manufactured on a wafer scale. At least one cap wafer having a plurality of getters disposed in corresponding recesses is coupled to a gyro wafer having a plurality of gyros. The resulting wafer assembly comprises a plurality of

separable gyro packages, wherein each gyro package includes at least one cap portion coupled to a base portion. Accordingly, a getter and an associated gyro is enclosed in each gyro package. Through eutectic bonding, each getter and corresponding gyro is vacuum sealed in the gyro package. The wafer assembly may then be diced along

5 predefined elongate through-holes in the cap wafer to provide separate gyro packages.

Many alterations and modifications may be made by those having ordinary skill in the art without departing from the spirit and scope of the invention. Therefore, it must be understood that the illustrated embodiments have been set forth only for the purposes of examples and that they should not be taken as limiting the invention as

10 defined by the following claims. For example, notwithstanding the fact that the elements of a claim are set forth below in a certain combination, it must be expressly understood that the invention includes other combinations of fewer, more or different elements, which are disclosed in above even when not initially claimed in such combinations.

15 The words used in this specification to describe the invention and its various embodiments are to be understood not only in the sense of their commonly defined meanings, but to include by special definition in this specification the generic structure, material or acts of which they represent a single species.

20 The definitions of the words or elements of the following claims are, therefore, defined in this specification to not only include the combination of elements which are literally set forth. In this sense it is therefore contemplated that an equivalent substitution of two or more elements may be made for any one of the elements in the claims below or that a single element may be substituted for two or more elements in a claim. Although elements may be described above as acting in certain combinations 25 and even initially claimed as such, it is to be expressly understood that one or more elements from a claimed combination can in some cases be excised from the combination and that the claimed combination may be directed to a subcombination or variation of a subcombination.

30 Insubstantial changes from the claimed subject matter as viewed by a person with ordinary skill in the art, now known or later devised, are expressly contemplated as being equivalently within the scope of the claims. Therefore, obvious substitutions now or later known to one with ordinary skill in the art are defined to be within the scope of the defined elements.

The claims are thus to be understood to include what is specifically illustrated and described above, what is conceptionally equivalent, what can be obviously substituted and also what incorporates the essential idea of the invention.

## WHAT IS CLAIMED IS:

1. A gyro package, comprising:

a base including a MEMS gyro;

a metallic seal ring disposed on the base;

5 a cap defining a recess;

a getter coupled to the cap and disposed in the recess;

a first alloy disposed on a bottom surface of the cap; and

10 a second alloy coupled to the metallic seal ring and the first alloy so as to seal in the gyro and the getter.

10 2. The gyro package of Claim 1, wherein the second alloy and the metallic seal ring comprise a common metal.

3. The gyro package of Claim 1, wherein the second alloy and the first alloy comprise a common metal.

15 4. The gyro package of Claim 1, wherein the second alloy comprises a preform.

5. A gyro package, comprising:

a base including a MEMS gyro;

a metallic seal ring disposed on the base;

a cap defining a recess;

20 a getter coupled to the cap and disposed in the recess;

a first alloy disposed on a bottom surface of the cap;

a spacer lattice disposed between the cap and the base, the spacer lattice having a top lattice surface and a bottom lattice surface; and

25 a second alloy disposed on the top lattice surface and the bottom lattice surface,

the second alloy being coupled to the metallic seal ring and the first alloy so as to couple the spacer lattice to the cap and the base.

6. The gyro package of Claim 5, further comprising:

a first preform coupling the first metallic alloy to the second alloy on the top lattice surface; and

a second preform coupling the metallic seal ring to the second alloy on the

5 bottom lattice surface.

7. A gyro package, comprising:

a base including a MEMS gyro;

a first cap coupled to the base so as to form a first cavity;

10 a second cap coupled to the first cap so as to form a second cavity, the first cap defining an aperture in fluid communication with the first cavity and the second cavity; and

a getter coupled to the second cap and disposed in the second cavity, wherein a vacuum is defined between the second cap and the base.

8. The gyro package of Claim 7, further comprising a first alloy applied to a

15 bottom surface of the second cap, wherein the getter is soldered to the first alloy.

9. The gyro package of Claim 8, further comprising a metallic seal ring applied to a top surface of the first cap and coupled to the first alloy.

10. The gyro package of Claim 9, wherein the metallic seal ring is coupled to the first alloy with a preform.

20 11. A method for manufacturing gyro packages on a wafer scale, comprising the steps of:

providing a gyro wafer with a plurality of base portions having gyros;

providing a cap wafer with a plurality of cap portions coupled to a plurality of getters;

25 activating the getters; and

eutectically coupling the cap wafer to the gyro wafer to form a plurality of vacuum sealed gyro packages.

12. The method of Claim 11, further comprising the step of applying a first alloy to a bottom surface of the cap wafer.

13. The method of Claim 12, further comprising the step of soldering the getters to the first alloy.

5 14. The method of Claim 12, further comprising the step of applying a second alloy to a top surface of the gyro wafer.

15. The method of Claim 14, wherein the step of applying a second alloy to a top surface of the gyro wafer comprises the step of disposing seal rings composed of the second alloy onto the top surface of the gyro wafer.

10 16. The method of Claim 14, wherein the step of eutectically bonding the cap wafer to the gyro wafer to form a plurality of vacuum sealed gyro packages comprises the step of bonding a third alloy to the first alloy and the second alloy.

15 17. The method of Claim 16, wherein the step of bonding a third alloy to the first alloy and the second alloy comprises bonding a preform composed of the third alloy to the first alloy and the second alloy.

18. The method of Claim 11, wherein the step of eutectically coupling the cap wafer to the gyro wafer to form a plurality of vacuum sealed gyro packages comprises the step of coupling the cap wafer and the gyro wafer to an intermediate wafer.

19. The method of Claim 18, wherein the step of coupling the cap wafer and  
20 the gyro wafer to an intermediate wafer comprises the step of coupling the cap wafer and the gyro wafer to a spacer lattice.

20. A method for manufacturing a gyro package, comprising the steps of:

applying a first alloy to a bottom side of a cap;

coupling a getter to the first alloy on the bottom surface of the cap;

activating the getter;

5 providing a base with a MEMS gyro on a top side;

applying a seal ring on the top side of the base; and

coupling the cap to the base with a second alloy so as to enclose the getter and

the MEMS gyro.

21. The method of Claim 20, the step of applying a seal ring on the top side of

10 the base comprises the step of applying a third alloy on the top side of the base.

22. The method of Claim 20, further comprising the step of providing the first alloy and the second alloy with at least one common metal.

23. The method of Claim 20, further comprising the step of providing the seal ring and the second alloy with at least one common metal.

15 24. The method of Claim 20, wherein the step of coupling the cap to the base with a second alloy so as to enclose the getter and the MEMS gyro comprises the step of eutectically bonding the first alloy and the seal ring to the second alloy.

25. A method for retrofitting an existing gyro package having a base portion with a gyro, and a existing cap portion coupled to the base portion, the method

20 comprising the steps of:

forming a hole in the existing cap portion;

coupling a getter to a bottom side of an additional cap portion;

activating the getter; and

coupling the additional cap portion to a top side of the existing cap portion to form

25 a vacuum sealed cavity in which the getter and the gyro are disposed.

26. The method of Claim 25, further comprising the step of applying a first alloy to a bottom side of the additional cap portion.

27. The method of Claim 26, further comprising the steps of:  
applying a second alloy to a top side of the existing cap portion; and  
coupling the first alloy to the second alloy with a third alloy.

28. The method of Claim 27, wherein:

5       the step of applying a second alloy to a top side of the existing cap portion  
comprises the step of applying a seal ring to the top side of the existing cap portion; and  
      the step of coupling the first alloy to the second alloy with a third alloy comprises  
the step of coupling the first alloy to the seal ring with a preform.

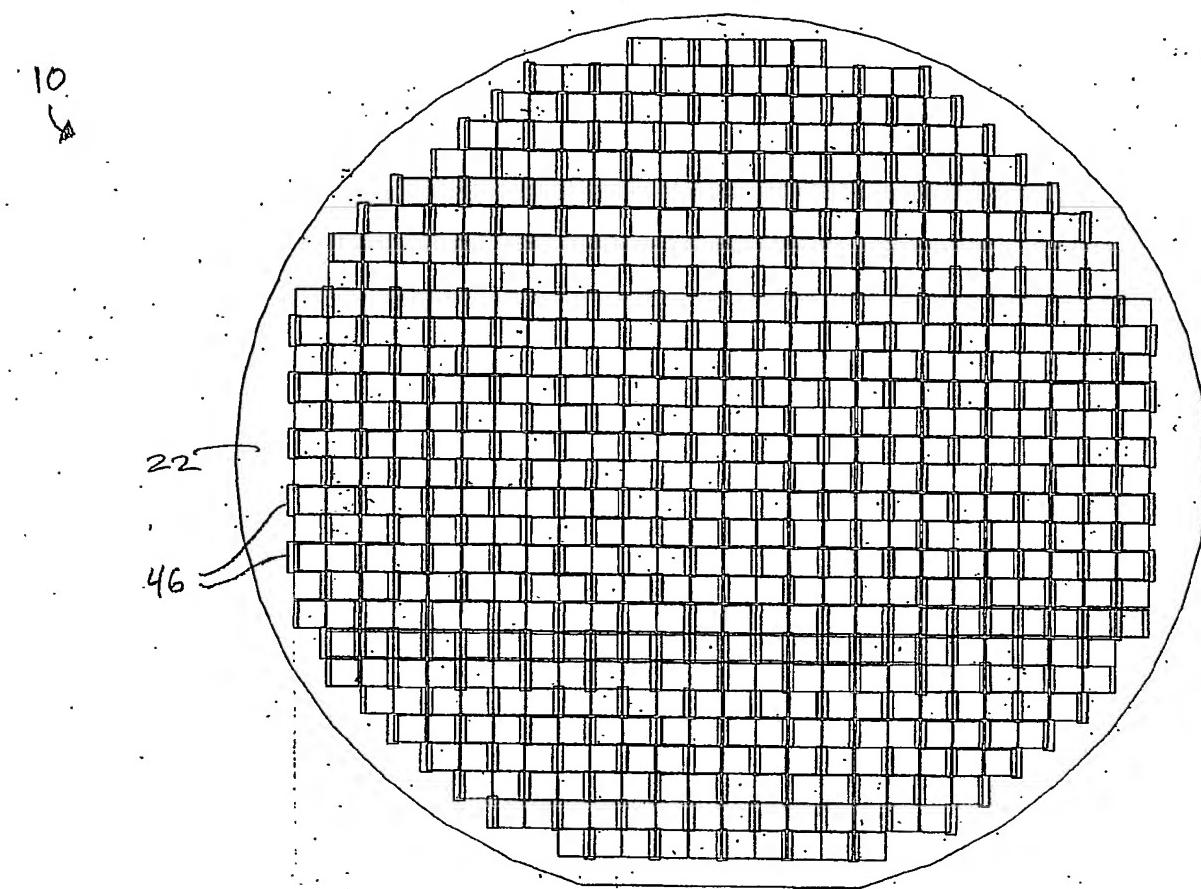


Fig. 1a. Top view of bonded wafer, showing cap wafer and MEMS gyro wafer.

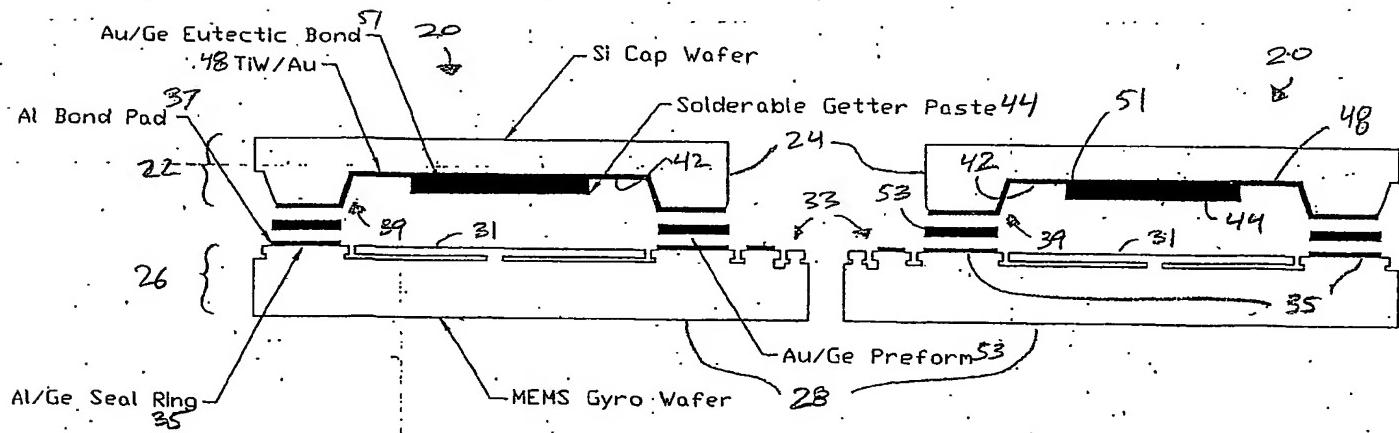


Fig. 1b. Wafer Bonding using Al/Au Eutectic Bond approach.  
(Cross Section View of Lid Sealing of One Die on Gyro Wafer)

100

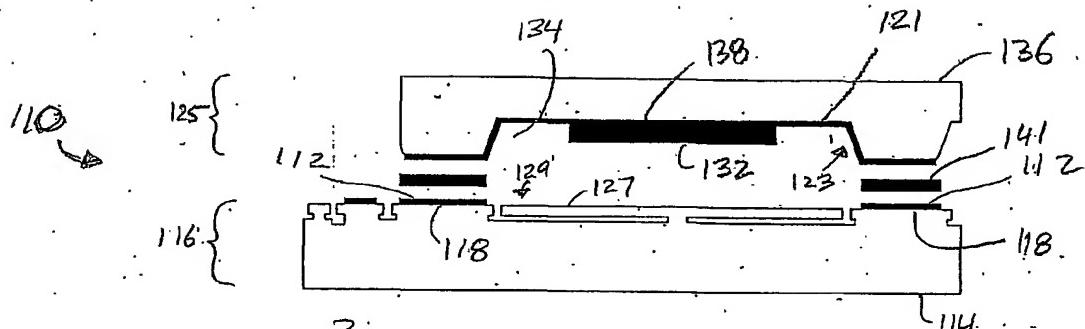


Fig. 2e. Wafer Bonding using Au/Sn Eutectic Bond and Silicon Spacer Lattice Approach.

200

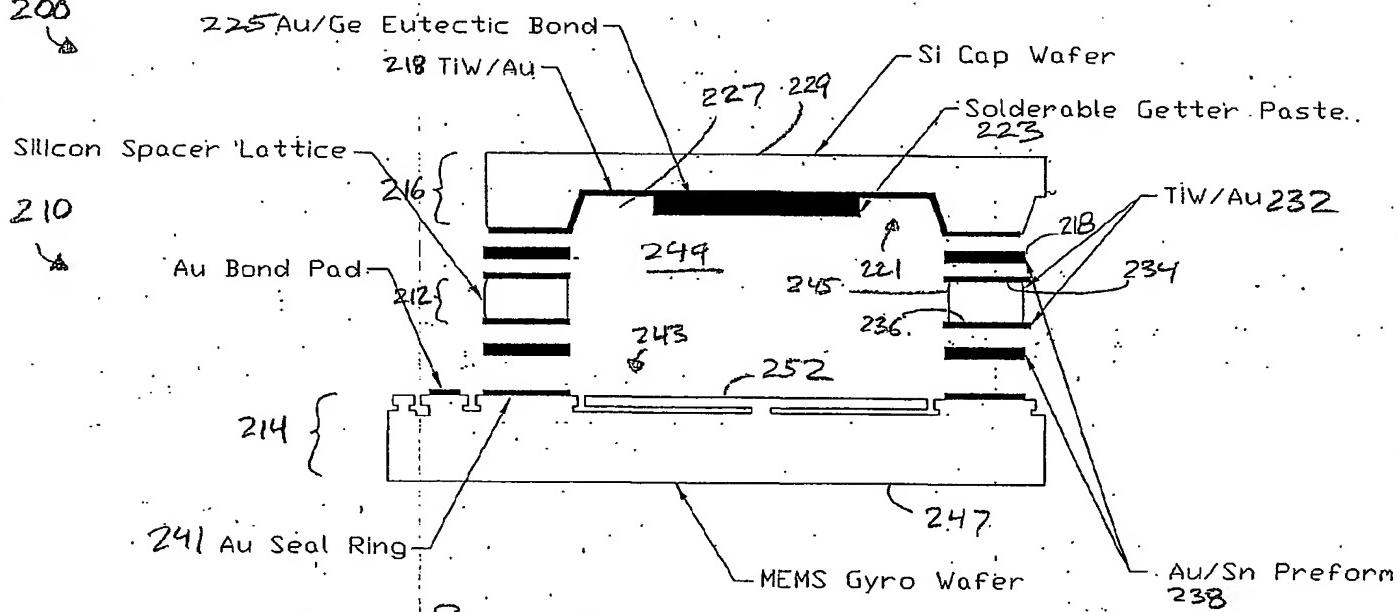


Fig. 2f. Wafer Bonding using Au/Sn Eutectic Bond and Silicon Spacer Lattice Approach.

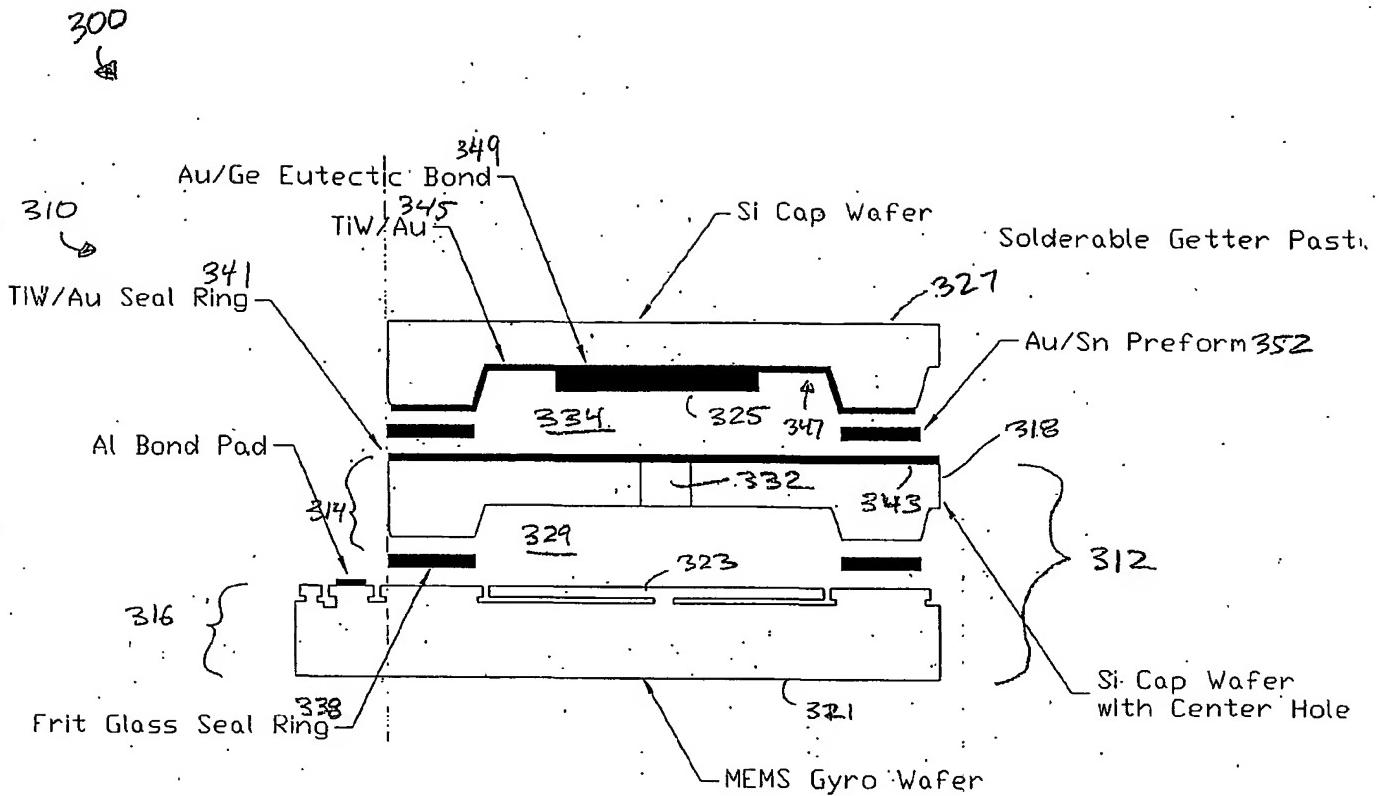


Fig. 3. <sup>4</sup> Wafer Bonding using Glass Frit Seal and Au/Sn, Eutectic Bond Approach.

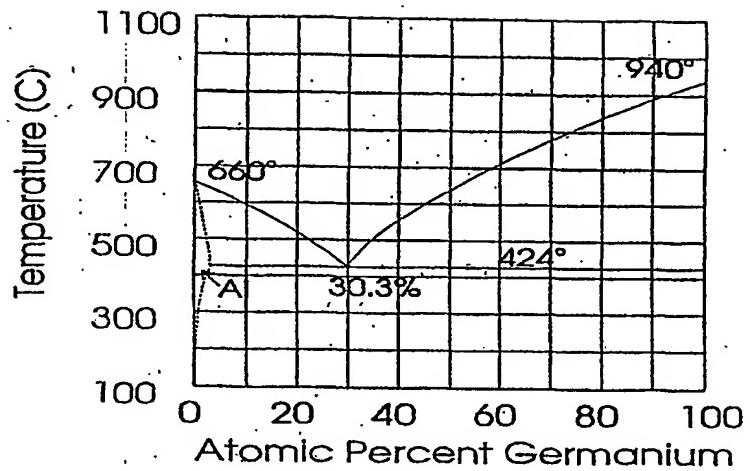


Fig. 5. Binary phase diagram of the Aluminum Germanium alloy system.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
30 May 2002 (30.05.2002)

PCT

(10) International Publication Number  
**WO 02/042716 A3**

(51) International Patent Classification<sup>7</sup>:

**H05K 5/06**

(21) International Application Number:

PCT/US01/44329

(22) International Filing Date:

27 November 2001 (27.11.2001)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

60/253,206 27 November 2000 (27.11.2000) US

(71) Applicant (for all designated States except US): MICROSENSORS INC. [US/US]; 3001 Redhill Avenue, Suite 4-109, Costa Mesa, CA 92612 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): EIDE, Floyd, K. [/US]; 3889 Mistral Drive, Huntington Beach, CA 92649 (US). NGUYEN, Andy, A. [/US]; 9882 West Ramm Drive, Anaheim, CA 92806 (US).

(74) Agent: LIN, Vic, Y.; Myers, Dawes & Andras LLP, Suite 1150, 19900 MacArthur Boulevard, Irvine, CA 92612 (US).

(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

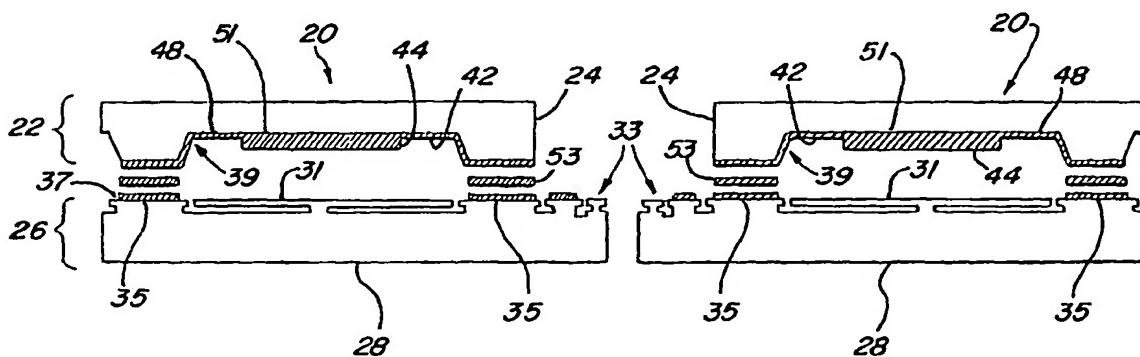
Published:

— with international search report

(88) Date of publication of the international search report:  
23 January 2003

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: WAFER EUTECTIC BONDING OF MEMS GYROS



(57) Abstract: A gyro package includes at least one cap portion (22) coupled to a base portion (28), a getter (44), a gyro (26), a sealed ring (35).

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/44329

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H05K 5/06

US CL : 174/52.3

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 174/52.3, 52.2; 257/704, 682, 684

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	US 5,792,984 A (BLOOM) 11 AUGUST 1998 (11.08.1998), SEE FIG 3	1-28
A	US 6,204,448 A (GARLAND ET AL) 20 MARCH 2001 (20.03.2001), SEE FIG 3A	1-28

Further documents are listed in the continuation of Box C.

See patent family annex.

• Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

30 JUNE 2002

Date of mailing of the international search report

12 SEP 2002

Name and mailing address of the ISA/US  
Commissioner of Patents and Trademarks  
Box PCT  
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

HUNG V. NGO

Telephone No. (703) 308-7674